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INVESTIGATION OF MAKE OR BUY AS A MEASURE IN INNOVATION RESEARCH: A PILOT STUDY

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1. PROBLEM STATEMENT

The functional locus of innovation* has been shown to be a very useful variable for the purposes of innovation research (1). Its usefulness stems from the strong correlations it displays with such dependant variables as frequency of successful innovation, innovation "type", etc., and its susceptability to reliable retrospective measurement. Unfortunately, however, it is also a very laborious task to collect data on the functional locus of innovation, and for this reason a more easily documented proxy variable would be very useful. Thus I would like, in this pilot study, to explore the utility of the measure "make or buy" as a proxy for the functional locus of innovation variable. Preliminary work on this measure has been very promising.

In the rest of this paper I will first discuss the preliminary data and the research methods by which it was acquired, and next discuss the potential utility of the proposed measure in innovation research.

2. METHODOLOGY

2.1 Definition of the Make or Buy Measure

If the process machinery utilized within a particular process step is built by the firm using it, then that machinery is coded as "made". On the other hand, if the process machinery utilized within a particular process step is bought or leased, then that machinery is coded as "bought" (leasing only occurs in the shoe making industry in our sample).

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* I define the "functional locus of innovation" (1) as the location in which costs are incurred (and usually, the work performed) that are involved in the creation of an innovation. In turn, that "locus", an organization and/or individual, is classified in terms of the functional relationship which it holds to the innovation at issue. Thus, if one is studying a sample of innovations impacting process machinery employed in a given industry, firms which use that machinery in production would be grouped in terms of that functional relationship into a "user" category, and manufacturers making the machinery would be grouped into a "manufacturer" category.

2.2 Sample Selection and Sample

In this pilot study I examine make or buy patterns in samples of process machinery selected from five industries: (1) the shoe making industry, (2) the corrugated box making industry, (3) the silicon semiconductor industry, (4) the miniature lamp industry, (5) the safety razor blade industry. These industries were selected because data on them was available and because they differed on industry structure variables such as number of firms, concentration ratio, age, etc.

All process machinery to be studied were determined for each industry in the following manner:

1. The major process steps for manufacturing the output product were identified, and they are shown in Table 1 below:

TABLE 1: The Major Process Steps for Each Industry

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2. For each process step identified (in each industry), the process machinery used in that step was included in the sample.
3. Because there were so many user firms in some of the industries examined, a subset had to be selected to be interviewed. This subset was selected by first sorting extant firms into three major categories according to size. The measures of "size" used in this pilot study differed for each industry according to data available for that industry. The selection of firms to be interviewed in each size category was not done with random procedures. They were selected rather based on ease of access to data, but I have no reason to believe that this selection procedure influenced the results of this study. The distribution of sampled firms according to size is shown in Table 2 below:

TABLE 2: Distribution of Companies According to Size and Sample Size

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TABLE 1: THE MAJOR PROCESS STEPS FOR EACH INDUSTRY

No.	INDUSTRY	Notation[a]	THE MAJOR PROCESS STEPS FOR MANUFACTURING[b]
1	SHOE MAKING (c)	F11 F12 F13 F14 F15	Cutting Fitting Lasting Bottoming Finishing
2	CORRUGATED BOX MAKING (d)	F21 F22	Corrugating Converting and Finishing
3	SILICON SEMICON-DUCTORS (e)	F31 F32 F33 F34 F35 F36 F37 F38 F39 F3,10 F3,11 F3,12 F3,13 F3,14 F3,15 F3,16	Growth of Single Silicon Crystal Wafer Slicing Wafer Lapping and Polishing Epitaxial Processing Oxidation Resist Coating Mask Alignment and Wafer Exposure Oxide Etching Junction Fabrication in Silicon Metalization Scribing and Dicing Mounting Wire Bonding Encapsulation Major Mask Preparation Steps Testing
4	MINIA-TURE LAMPS	F41 F42 F43 F44 F45	Glassmaking Bulbmaking Basemaking Assemblying Packaging
5	SAFETY RAZOR BLADES	F51 F52 F53 F54	Sharpening Preparation Steps Sharpening Coating Packaging

a: KEY: Fij = Major Process Step j within industry i.

b: The sources for compilation of the major process steps in each industry are as follows:
1. SHOE MAKING: "The Art & Science of Footwear Manufacturing", American Footwear Industries Association, 1611 N. Kent Street; Arlington, Virginia 22209, p. 29.
2. CORRUGATED BOX MAKING: "Corrugated Box Manufacturers' Handbook", Third Edition, S&S Corrugated Paper Machinery Co., Inc., p. vii.

TABLE 1: (continued)

3. SILICON SEMICONDUCTORS: "The Dominant Role of the User in Semiconductor and Electronic Subassembly Process Innovation", Eric von Hippel, IEEE Transactions on Engineering Management, Vol. EM-24, No.2, May 1977, Table I, p. 64. (In addition, TESTING is added to the list compiled by von Hippel.)
4. MINIATURE LAMPS: One knowledgeable person in one firm was asked to identify the major process steps in the industry, and information was checked with persons in the other sampled firms.
5. SAFETY RAZOR BLADES: (Same procedure as in the miniature lamp industry.)

c: Substeps for each major process step are shown in greater detail in Appendix A.

d: Major categories of process machinery within each major process are shown in Appendix B.

e: Initial commercial practice and major improvements (in the process machinery) are shown more in detail in Appendix C.

TABLE 2: DISTRIBUTION OF COMPANIES ACCORDING TO SIZE AND SAMPLE SIZE

No.	INDUSTRY	SIZE CATEGORY[a]	DISTRIBUTION OF FIRMS [b]	SAMPLE SIZE	INDUSTRY TOTAL No. OF FIRMS	INDUSTRY TOTAL SAMPLE SIZE
1	SHOE MAKING	L: output/year of nonrubber shoes $x \geq 4$m pairs	26	5		
		M: $.2m \leq x < 4m$	195	5		
		S: $x < .2m$	113	5	334	15
2	CORRUGATED BOX MAKING	L: total # of plants $x \geq 15$	19	5		
		M: $2 \leq x < 15$	36	5		
		S: $x = 1$	> 170	5	>225	15
3	SILICON SEMICONDUCTORS	L: output/year dollar value $x \geq \$400m$	10	5		
		M: $\$50 \leq x < \$400m$	40	5		
		S: $x < \$50m$	>100	5	>150	15
4	MINIATURE LAMPS	L: market sh. $x \geq 35\%$	1	1		
		M: $10\% \leq x < 35\%$	3	3		
		S: $x < 10\%$	2	2	6	6
5	SAFETY RAZOR BLADES	L: (-)	1	1		
		M: (-)	1	1		
		S: (-)	>1	1	>3	3

a: For each industry the breakpoint values for the size categories were discussed with one knowledgeable person in one firm and information was checked with persons in the other sampled firms, except for the Safety Razor Blade industry, where categorization was done by people in the largest company, without giving information of the breakpoint values.

b: For each industry the sources for compilation of the total number of firms in each size category were as follows:

1. SHOE MAKING: "Footwear Manual 1980", American Footwear Industries Association; 1611 N. Kent St., Arlington, VA 22209 (Table 44, p.41; the data is from 1977).
2. CORRUGATED BOX MAKING: "Paperboard Packaging's Official Container Director", Vol. 67, No. 1, Spring 1979. (Only firms with at least one corrugator is counted.)

TABLE 2: (continued)

3. SILICON SEMICONDUCTORS: Persons in the sampled firms. (One knowledgeable person in one firm was asked to estimate the number of firms in each size category and information was checked with persons in the other sampled firms.) (The total number of firms in the industry was computed from: "Semiconductor Industry Association", 1979 Yearbook and Directory, 20380 Town Center Lane, Suite 155, Cupertino, CA 95014.)
4. MINIATURE LAMPS: Taken from internal company document (provided by one of the companies in the industry). (The data is from 1978.)
5. SAFETY RAZOR BLADES: Knowledgeable persons in one sampled firm.

2.3 Data Collection

Data was collected from sources of industry statistics cited in the notes to Tables 1 and 2, and from telephone interviews with process machinery using firms. The telephone interviews were conducted with the production manager - and the R&D manager in firms which had both - in the sampled firms. (If it was a corporation with many plants, information from both headquarter and several plants was aquired.) Each interviewee was asked the following questions regarding each major process step identified for their industry:

1. Do you make or buy the process machinery utilized in ________ process step?
2. How many years have you made (bought) that machinery?
3. Do you know of any other user of process machinery in your industry, which has a different pattern concerning make or buy than you have?

3. FINDINGS

3.1 Patterns of Make or Buy in the Sampled Firms

The findings concerning patterns of make or buy in the sampled firms are shown in Figure 1 below:

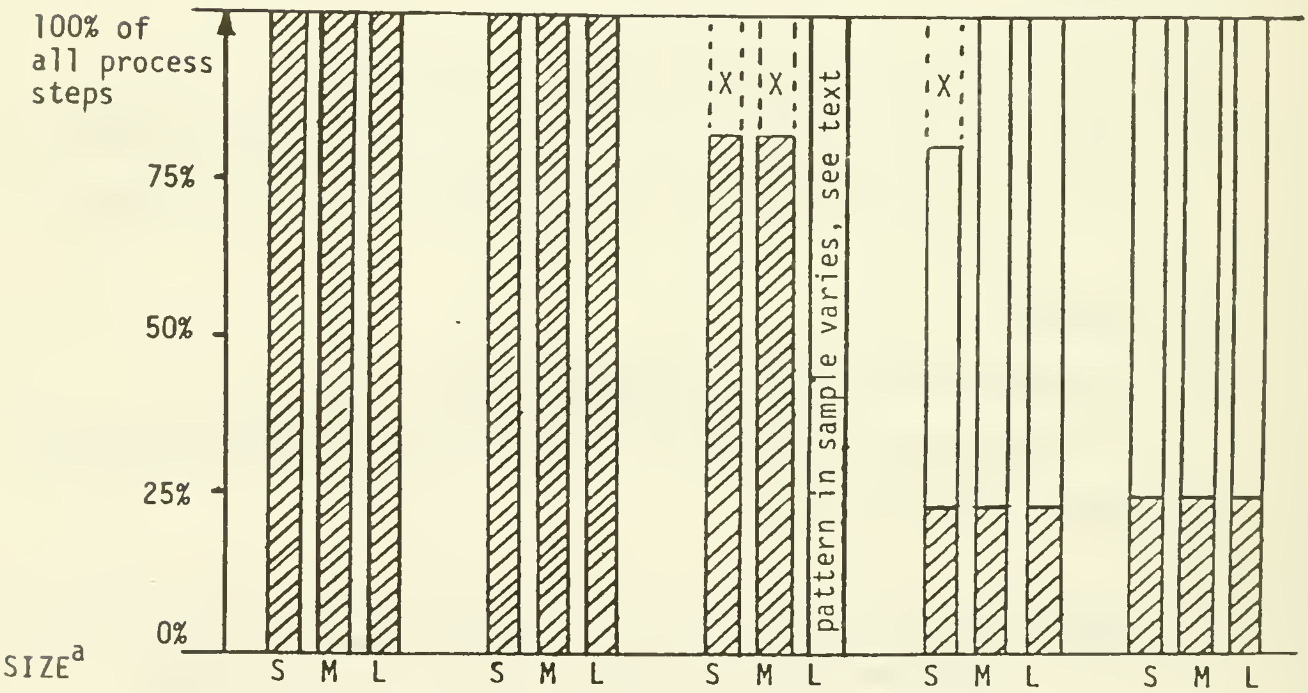
FIGURE 1: Level of Make or Buy in the Sampled Firms of Process Machinery Used in the Major Process Steps for Manufacturing in Five Industries

Note that the data reveals strong differences in level of make or buy across "groups" of industries, but no differences across size categories within a given industry except for the silicon semiconductor industry. Thus, we see that the level of buy (or lease) is 100% for the sampled firms in the shoe making industry, and 100% buy in the corrugated box making industry. On the other hand, the level of make is 80% and 75% in the miniature lamp and safety razor blade industry, respectively. We found firms sampled in these industries purchased packaging machinery only.

FIGURE 1: LEVEL OF MAKE OR BUY IN SAMPLED FIRMS OF PROCESS MACHINERY USED IN THE MAJOR PROCESS STEPS FOR MANUFACTURING IN FIVE INDUSTRIES

KEY:

- ☐ persistent make, basically 100% internally, for at least the 10 past years
- ▨ persistent buy, (or buy or lease, in the shoe making industry), for at least the 10 past years
- X process step not carried out internally



Sample size:	5 5 5	5 5 5	5 5 5	2 3 1	1 1 1
Total no of firms in industry:	334	>225	>150	6	>3
INDUSTRY:	SHOE MAKING	CORRUGATED BOX MAKING	SILICON SEMICONDUCTORS (b)	MINIATURE LAMPS (c)	SAFETY RAZOR BLADES

a: Size categories as in Table 2 (S=small, M=medium sized, L=large).

b: For the small and medium sized firms, process steps not carried out internally (coded X in the figure) are: growth of single silicon crystal; wafer slicing; and wafer lapping and polishing.

c: For the two small firms, the code X refers to the process step glassmaking. Also one of the three medium sized firms did not carry out glassmaking inhouse, but that is not shown in the figure.

In the silicon semiconductor industry on the other hand, the patterns of make or buy proved less consistent both across size categories of firms, and also within the "large" firm category. With respect to size categories we found that, while small and medium sized firms bought all their process machinery, some of the large firms sampled both bought and made process machinery. More specifically, of the five sampled firms in the "large" firm category, the data was as shown in Table 3 below:

TABLE 3: Make or Buy Pattern of Five Sampled Firms in the "Large" Firm Category in the Silicon Semiconductor Industry

Note from Table 3 that two of the five sampled firms make almost no process machinery, while the other three firms make 25% "or more". (Two of those firms regarded information as to what process machinery they made as proprietary.) In one firm a shift from basically 100% make to 100% buy was observed to occur in about 13% of its process steps within the 10 past years.

4. DISCUSSION AND CONCLUSION

4.1 Discussion of the Potential Utility of the Make or Buy Measure as a Proxy Variable for the Functional Locus of Innovation

In section 3 we saw that the miniature lamp and safety razor blade firms in our sample made most of their process machinery; the corrugated box and shoe firms in our sample bought (or leased) all of their process machinery; and for the sampled firms in the silicon semiconductor industry the pattern was mixed. In order for make or buy to serve as a proxy for the functional locus of innovation, theses findings - where make is assumed a proxy for "innovate" - must map well with data available on the functional locus of innovation. Currently, a small amount of data is available on the functional locus of innovation for three of the five industries whose make or buy pattern I have

TABLE 3: MAKE OR BUY PATTERN OF FIVE SAMPLED FIRMS IN THE "LARGE" FIRM CATEGORY IN THE SILICON SEMICONDUCTOR INDUSTRY

Company	Consistent pattern for the 10 past years		Shift in pattern within 10 years	na
	buy(%)	make (%)		
1	100	-	-	
2	94	6[a]	-	
3	31[b]	25[c]	13[d]	31
4	-	> 25	-	e
5	-	> 25	-	e

a: Process machinery made was utilized in epitaxial processing.

b: Process machinery bought was utilized in wafer slicing, wafer lapping and polishing, mask alignment and wafer exposure, junction fabrication in silicon, major mask preparation steps.

c: Process machinery made was utilized in oxidation, resist coating, wire bonding, computerized testing.

d: In about 13% of the process steps (growth of single silicon crystal and epitaxial processing), a shift from basically 100% make to 100% buy was observed within the 10 past years. (Of the residual 31% of the process steps, information as to what process machinery was made was regarded as proprietary information.)

e: Company reported that it made more than the third company, i.e. 25%, but information as to what process machinery was made was ragarded as proprietary information.

examined in this pilot study. These data (whose nature differs from industry to industry) are summarized in Table 4 below:

TABLE 4: Observed Make or Buy Level Compared to Available Data on the Functional Locus of Innovation in Three of the Five Sampled Industries

I suggest that the slim data base in Table 4, although crude, suggests that user making of process machinery may indeed be associated with the presence of user process machinery innovation. This seems promising for our proxy variable. I propose that the make or buy pattern needed to strongly suggest a manufacturer locus of innovation is 100% buy - because, even a small percentage of make could indicate a user locus of innovation for reasons which will be discussed. Further discussion of how well our measure of make or buy maps with the functional locus of innovation will be carried out below for each industry on which we have data.

As seen from Table 4, in the miniature lamp industry our measure shows a make level (for all firms) of 80% (where only packaging equipment were purchased). Further, it should be noted that the make pattern has been consistent for all firms, not only for the ten past years, but for all their years of operation. Our Table 4 information on the source of machinery innovation is found in a book by James Cox called "A Century of Light" (2). Cox describes 6 major lamp equipment innovations - and informs us that all of these were developed by equipment users. Cox mentions no manufacturer innovations. (In fact, users inform me that no general manufacturer for lamp equipment exists.) Thus, although the list of the 6 significant innovations is not claimed to be exhaustive, the data does suggest that the functional locus of innovation is a user locus. If this is true, our make or buy data does accurately serve as a proxy for the functional locus of innovation in the miniature lamp industry.

TABLE 4: OBSERVED MAKE OR BUY LEVEL COMPARED TO AVAILABLE DATA ON THE FUNCTIONAL LOCUS OF INNOVATION IN THREE OF THE FIVE SAMPLED INDUSTRIES

Industry	Consistent pattern for at least the 10 past years user % make	Available data on the functional locus of innovation innovation user	 innovation manufacturer
MINIATURE LAMPS	80% (n=6)	6[a] significant innovations credited to the user community	
SILICON SEMICONDUCTORS	>25%[b] (only some large firms are found to make)	71% (n=32, na=4)[c] (only some large firms are found to innovate)	17%
SHOE MAKING	0% (n=15)	17% (patents held by shoe machinery using firms)	60%[d] (patents held by shoe machinery manufacturers)

a: The list of the 6 significant innovations is compiled from the source below. The list is not claimed to be exhaustive and general lamp equipment are listed.
Source: "A Century of Light", James A. Cox, A Benjamin Company/Rutledge Book, 1979.

b: Of the five sampled firms in the "large" firm category, one firm was found to make process machinery utilized in 25% of its process steps, whereas two other firms reported to make more than the first firm (i.e. 25%) but both firms regarded information as to what process machinery they made as proprietary.

c: Of 32 (na=4) sampled process machinery innovations in the silicon semiconductor industry, 20 innovations (5 initial commercial practice, lo major improvements, 5 minor improvements) were user dominated, while only five innovations (2 major improvements, and 3 minor improvements) were manufacturer dominated, (other patterns were 12%).
Source: "The Dominant Role of the User in Semiconductor and Electronic Subassembly Process Innovation", Eric von Hippel, IEEE Transactions on Engineering Management, Vol. EM-24, No. 2, May 1977. (Table II, p.67).

TABLE 4: (continued)

d: 40% of all United States patents (as of 15 December 1947) in what relate to shoe machinery (nailing and stapling, boot and shoe making, sewing, cutting and punching, eyeletting) is held by United Shoe Machinery Corporation (USM). Of those other than USM holding shoe machinery patents (in the class "boot and shoe making"), shoe firms hold 17% and shoe machinery firms hold 20% (where the latter percentage is added to USM's 40% yielding 60% for the manufacturer category).
Source: "United States v. United Shoe Machinery Corporation. An Economic Analysis of an Anti-Trust Case", Carl Kaysen, (Table 4, p. 80, and Table 5, p. 81).

In the silicon semiconductor industry, von Hippel (3) reports a user locus of innovation in 71% of 32 (na=4) sampled process machinery innovations (as shown in Table 4). Further, he found that four out of the five innovating user firms identified were ranked among the largest eight of 50 extant firms in terms of market share (4). In agreement with von Hippel's findings, our measure showed that only some of the large semiconductor machinery using firms make some of their process machinery. Thus, the "make side" of our measure appears to be accurately associated with where innovation takes place in the user industry. Note that, although the level of make is modest, about 25% (two large firms reported to make more than 25%), even a modest level of "user make" can be associated with a high level of user innovation, because, as von Hippel (4) found, user process machinery innovations (innovated by some large users) were often transferred to equipment manufacturers who built the user-developed equipment commercially and sold it to non-innovating firms. These latter user firms would then logically report, as our data shows, that they "buy" their equipment. Thus, we conclude that our measure can satisfactory serve as a proxy for the functional locus of innovation in the silicon semiconductor industry.

All the shoe machinery users we sampled reported that they bought (or leased) their equipment. This fits our pattern for a manufacturer locus of innovation. Nevertheless, since we only sampled 15 firms out of 334 shoe firms, and because, even a modest level of make by some other user firms (not sampled) could be responsible for a high level of user innovation (as was the pattern in the silicon semiconductor industry) we should be cautious. To address this problem, we asked sampled shoe firms to identify any other user (of process machinery) which they knew had a different make or buy pattern than themselves (recall that this was question 3 in our telephone interviews). All immediately referred to one company Wellco, as the one company, and the only one they knew, which made one category of process

machinery 100% internally. Upon calling up the president of the company, I learned that Wellco had indeed been making inhouse, since 1939, process machinery utilized in the lasting operation for low cost boots. The above uniform response of interviewees makes me feel it unlikely that our small sample could have overlooked some other "unknown" shoe firm(s) which were making some of their process machinery and thus providing a source of user innovation for the industry.* (That Wellco alone, however, should be responsible for a possible high level of user innovation (in all categories of shoe machinery) simply is impossible based on the fact that the company's make activities were concentrated in a narrow field.) These results suggest a manufacturer locus of innovation, and this is congruent with our Table 4 data which shows manufacturers hold more than three times as many patents as the users. Thus, we suggest that our measure can serve as a proxy for the functional locus of innovation in the shoe making industry too.**

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* Data from the other sampled industries suggests that they all are very well informed about their own industry and each others make or buy pattern. For example in the silicon semiconductor industry, all the interviewed persons in the sampled firms were perfectly aware of that "some of the big ones make some of their own equipment". And not only that, but practically all persons interviewed could name the companies they expected to make equipment inhouse, and the same names were showing up every time. Moreover, in some cases the persons also knew what kind of equipment some of the large firms were making internally, and this was especially true for the large companies themselves. Further, these findings were repeated when contacting two equipment manufacturers (not claimed to be the largest) and persons at SEMI (Semiconductor Equipment Manufacturers Industry Association). In the miniature lamp and safety razor blade industries, they all seem to know practically everything about what kind of process machinery which was made or bought by the other companies in their industry. Finally, in the corrugated box making industry, no one contacted could refer to any cases where (another) box plant had been making one or more process machinery inhouse, and these findings were repeated by persons contacted in four of the largest manufacturers of corrugated box industry equipment. (It should be noted that the data above reflects <u>industry</u> pattern of make or buy that is identical to our <u>sample</u> pattern of make or buy which, of course, increases our confidence in the representativeness of our industry samples.)

**For the safety razor blade and corrugated box making industries, we have no available data for testing our proxy variable, but the successful test results from the other industries suggest a user locus of innovation in the

4.2 The Utility of the Make or Buy Variable in Innovation Research: An Example

In the preceding section, we found, on the basis of crude data, that make or buy was a promising proxy for the functional locus of innovation. As discussed at the beginning of the paper, its advantage over direct empirical measurement of the locus of innovation lies with the relative ease with which reliable empirical data on make or buy can be obtained. As an example of the utility this difference offers innovation researchers, we have quickly obtained data on make or buy sufficient to suggest a relationship between concentration ratios and the locus of innovation.* (Collection of equivalent direct data on the functional locus of innovation would have been an exceedingly laborious task.) Note in Table 5 below we see a strong correlation between high concentration ratio (>70%) and consistent make pattern by all users in industry, and between low concentration ratio (<30%) and consistent buy pattern by all users in industry. (Note that packaging, in the case of machinery used only in one industry, has a general purpose character and can be applied in many industries. Thus, it is possible single industry concentration ratios do not apply here.)

TABLE 5: Association of Concentration Ratio with Consistent Patterns of Make or Buy of Process Machinery Utilized in the Major Process Steps for Manufacturing in Five Industries

In future work, I plan to further develop the "make or buy" measure and to utilize it to explore innovation research issues such as concentration patterns observed in Table 5.

(continued)
safety razor blade industry (where all the three sampled firms reported a consistent make for 75% of their process machines in all their years of operation), and our proxy variable suggests a manufacturer locus of innovation in the corrugated box making industry (where all the sampled firms were found to buy all their process machinery for at least the ten past years).

* A similar argument is set forth by von Hippel discussing appropriability of innovation benefit as a predictor of the functional locus of innovation (1).

TABLE 5: ASSOCIATION OF CONCENTRATION RATIO WITH CONSISTENT PATTERNS OF MAKE OR BUY OF PROCESS MACHINERY UTILIZED IN THE MAJOR PROCESS STEPS FOR MANUFACTURING IN FIVE INDUSTRIES

Industry	Concentration ratio[a]	Consistent pattern for at least the 10 past years
SAFETY RAZOR BLADES	> 90% (except packaging)*	Make (except packaging)
MINIATURE LAMPS	> 70% (except packaging)*	Make (except packaging)
SILICON SEMICONDUCTORS	53%	Mixed
CORRUGATED BOXES	< 30%	Buy
SHOE MAKING	26%	buy

*Note that packaging, in the case of machinery used only in one industry, has a general purpose character and can be applied in many industries. Thus, it is possible that single industry concentration ratios do not apply here.

a: Compilation of concentration ratios (the "four largest firm ratio") were taken from the following sources:
1. SAFETY RAZOR BLADES: Knowledgeable persons in one sampled firm.
2. MINIATURE LAMPS: Taken from internal company document (provided by one of the companies in the industry).(The data is from 1978.)
3. SILICON SEMICONDUCTORS: "The Semiconductor Industry: A Survey of Structure, Conduct, and Performance", Bureau of Economics, Jan. 1977. (Table II-6, p.20.)
4. CORRUGATED BOX MAKING: "Company Shipment Summary", Fibre Box Industry Association, Chicago Illinois 60631. (The largest company had in 1972 less than 7% of the total corrugated market (square feet shipped).)
5. SHOE MAKING:"Concentration Ratios in Manufacturing Industry", U.S. Senate, Committee on the Judiciary, Subcommittee on Antitrust and Monopoly, Report, 1963, Part I (Washington: 1966). In Scherer F.M.:"Industrial Market Structure and Economic Performance", Rand McNally Colledge Publishing Company, Chicago 1970.

APPENDIX A: SUBSTEPS WITHIN EACH MAJOR PROCESS STEP FOR SHOE MANUFACTURING[a]

1. CUTTING

2. FITTING
   - perforating
   - pinking
   - skiving
   - splitting
   - doubling
   - seam rubbing and taping
   - taping top lines
   - cementing and folding
   - eyeletting
   - lacing
   - high frequency heating operations

3. LASTING
   - fasten insole
   - assemble
   - pull over
   - tack side last
   - cement forepart last
   - tack heel seat last
   - toe last

4. BOTTOMING
   - cemented
   - molded
   - sewn

5. FINISHING
   - cleaning and spraying
   - inspection
   - packaging

a: Source: The Art and Science of Footwear Manufacturing. American Footwear Industries Association, 1611 N. Kent Street; Arlington, Virginia 22209.

APPENDIX B: MAJOR CATEGORIES OF PROCESS MACHINERY WITHIN EACH MAJOR PROCESS STEP FOR CORRUGATED BOX MANUFACTURING[a]

1. CORRUGATING
   - mill roll stands
   - preheater
   - single facer
   - preconditioner
   - preheater
   - glue station
   - double facer
   - slitter
   - cutoff knife
   - sheet collector

2. CONVERTING AND FINISHING
   - slitter-creaser
   - printer slotter
   - diecutting

   } flexographic printer slotter with creasing and slotting section

   - automatic folder-tapers
   - automatic folders for stiching & lap gluing

   } folder gluers

   - semiautomatic tapers
   - stichers
   - counter-stackers, tying and strapping

a: Source: Corrugated Box Manufacturers' Handbook. Third Edition, S&S Corrugated Paper Machinery Co., Inc., 1965.

APPENDIX C: INITIAL COMMERCIAL PRACTICE AND MAJOR IMPROVEMENT IN PROCESS MACHINERY UTILIZED IN SOME OF THE MAJOR PROCESS STEPS FOR SILICON SEMICONDUCTOR MANUFACTURING[a]

Major Process Step	Initial Commercial Practice	Major Improvement
. Growth of Single Silicon Crystal	RF Crystal Puller	Resist Heated Crystal Pulling Dislocation Free Crystal Pulling Auto Diameter Control
. Wafer Slicing	High Precision Saws	ID Saw
. Wafer Lapping and Polishing	Optical Polishing equipment and technique	Chem-mech Polishing (SiO_2) Chem-mech Polishing (Copper)
. Epitaxial Processing (optional process step)	Pancake Reactor	Horizontal Reactor Barrel Reactor
. Resist Coating	Wafer Spinner	High Accel. Wafer Spinner 11 minor improvement innovations
. Mask Alignment and Wafer Exposure	Mask Aligner	Split Field Optics Aligner Auto Mask Aligner
. Junction Fabrication in Silicon	Grown Junction	Diffused Junction (Furnace) Ion Implantation Accelerator
. Scribing and Dicing	Jig & Fixture	Mechanical Scriber and Dicer Laser Scriber and Dicer
. Wire Bonding	Solder Bonding	Thermocompression Bonding Ultrasonic Bonding
Major Mask Preparation Steps		
. Mask Graphics	Handcut Rubylith Patterns	NC (Optical) Pattern Generator NC (Electron Beam) Pattern Generator
. Mask Reduction	Two stage step and repeat reduction process	

a: Source: "The Dominant Role of the User in Semiconductor and Electronic Subassembly Process Innovation", Eric von Hippel, IEEE Transactions on Engineering Management, Vol. EM-24, No. 2, May 1977, Table I, p. 64.

REFERENCES

1. Von Hippel, Eric: "Appropriability of Innovation Benefit as a Predictor of the Functional Locus of Innovation", Working Paper, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Mass., June 1979.

2. Cox, James A.: "A Century of Light", A Benjamin Company/Rutledge Book, 1979.

3. Von Hippel, Eric: " The Dominant Role of the User in the Semiconductor and Electronic Subassembly Process Innovation", IEEE Transactions on Engineering Management, Vol. EM-24, No. 2, May 1977.

4. __________ :"Transferring Process Equipment Innovations from User-Innovators to Equipment Manufacturing Firms", R&D Management, Vol. 8, No. 1, Oct. 1977.

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